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Results of a Scientific Workshop to Evaluate the Status of Harbor Porpoises (*Phocoena phocoena*) in the Western North Atlantic

Edited by

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EXECUTIVE SUMMARY

During February 23-25, 1994, a workshop was held in Woods Hole, Mass. where scientists from the United States, Canada, and England assessed the status of harbor porpoises (*Phocoena phocoena*) from the western North Atlantic. This was done by reviewing information on population structure, and estimates of abundance, bycatch, and population growth rate. In addition, habitat requirements were hypothesized by investigating physical, biological, and anthropogenic factors correlated with the distribution and abundance of harbor porpoises.

A 1992 workshop (NEFSC 1992) proposed the working hypothesis that the population structure for harbor porpoises found in waters from North Carolina to Newfoundland consisted of three subpopulations - Gulf of Maine/Bay of Fundy, Gulf of St. Lawrence, and Newfoundland. Although presently there is insufficient evidence to reject this hypothesis, recent information on mobility of individuals, results from a mitochondrial genetic study, and two abundance surveys suggests that the putative subpopulations are not as isolated from one another as was thought previously. To determine the degree of discreteness of these putative subpopulations, a multidisciplinary approach was recommended to include mtDNA sequencing, microsatellite DNA methods, tooth ultrastructure characteristics, life history parameters, and individual movement studies.

Abundance estimates for the Gulf of Maine/Bay of Fundy region during the summers of 1991 and 1992 are 37,500 (%CV=28.8, 95% CI 26,700 to 86,400) and 67,500 (%CV=23.1, 95% CI 32,900 to 104,600), respectively. The weighted average estimate was 47,200 (%CV=19.0, 95% CI 39,500 to 70,600), where each estimate was weighted by the inverse of its variance. The reason for the nearly twofold, but statistically insignificant, increase between 1991 and 1992 is unknown, but may reflect a real change in abundance due to a distribution change or methodological sampling error. Methods to investigate this difference were recommended. Abundance estimates were not made for the Gulf of St. Lawrence or Newfoundland regions. However, an aerial survey of the Gulf of St. Lawrence is being considered for 1995, which might coincide with a proposed aerial-shipboard survey in the Gulf of Maine/Bay of Fundy.

Bycatch estimates were available for the Gulf of Maine and Gulf of St. Lawrence, but not for the U.S. Mid-Atlantic, Bay of Fundy, and Newfoundland regions. Discussions of potential biases in the Gulf of Maine estimate included (1) harbor porpoises that fell out of gillnets before being recorded, (2) possible nonrepresentative vessel selection in the sea sampling program, and (3) inaccurate reporting of the number of vessels, trips and fish landings in the weighout database. It was concluded that the sea sampling and weighout databases are probably not biased to a large degree. However, it was demonstrated that harbor porpoises do fall out of the net before they reach the deck; therefore, bycatch rates estimated from unobserved hauls will downwardly bias the total bycatch estimate. Consequentially, bycatch estimates reported in the past are likely downwardly biased and should be recalculated. For the Gulf of St. Lawrence, a bycatch estimate of 1900 harbor porpoises per year has been made using mail surveys conducted in 1989 and 1990. A low return rate of the mail surveys was reported, thus, raising questions about reliability of the bycatch estimates. An additional study conducted during 1992 in a small section of the Gulf of St. Lawrence could be used to determine if the mail survey was a reliable method.

Information needed to estimate potential population growth rate of harbor porpoises has substantial uncertainty, and data for some parameters do not exist. To account for this uncertainty, a simulation method was developed to incorporate uncertainty in harbor porpoise age of sexual maturity, age-specific reproductive output, and other life table parameters, thus resulting in a distribution of potential growth rate estimates. It was concluded that the potential growth rate is unlikely to be greater than 10% per year and, if the best estimate is the median of the distribution, then the best estimate of the potential growth rate is about 4% per year. However, it is unknown whether the best estimate is the median. Future research into this question was discussed.

Harbor porpoise habitat was defined by those collective factors correlated with the distribution and abundance of harbor porpoises. Physical factors thought to influence harbor porpoise distribution included water temperature, water depth, vertical mixing, and bottom topography. Biological factors included distribution of primary prey species (herring and silver hake), predators, maternal requirements (both spatial and nutritional), other prey species, and potential competitors. Anthropogenic factors included human disturbance and commercial fishing operations. There were sufficient data to examine the degree of correlation between water temperature, depth, vertical mixing, bottom topography, and harbor porpoise distribution and relative density. During the summer in the Gulf of Maine/Bay of Fundy region, high densities of harbor porpoises were found in waters that were 11 to 14°C, shallower than 100 fathoms, often vertically mixed, and contained herring and silver hake. Methods to continue this investigation were discussed.

Because of uncertainties in population structure, seasonal movements, and estimates of abundance, bycatch, and population growth rate, it was not possible to assess the status of harbor porpoises in the western North Atlantic. Methods of assessing the biological significance of bycatch were discussed given several hypothesized genetic structures and seasonal movement patterns. One hypothetical population structure was that harbor porpoises in the Gulf of Maine/Bay of Fundy region are isolated from other harbor porpoises in the western North Atlantic. In this situation, the workshop recommended that an assessment of biological significance be made after Gulf of Maine bycatch estimates are recalculated and Bay of Fundy summer bycatch is estimated, perhaps using a rough estimation procedure. It was noted, however, that this total bycatch estimate will be biased downward because bycatch in the U.S. Mid-Atlantic region is not known and, at this time, cannot be approximated. The workshop noted that several other hypothetical population structures were also consistent with available information. Thus, to complete an accurate assessment of the harbor porpoise status the following was recommended: (1) determine genetic population structure and seasonal movements, (2) estimate summer abundance in the Gulf of St. Lawrence and around Newfoundland, (3) estimate bycatch in the U.S. Mid-Atlantic region, Bay of Fundy, and around Newfoundland, in addition, update estimates from the Gulf of St. Lawrence, and (4) recalculate Gulf of Maine bycatch estimates.

INTRODUCTION

Increasing concern about the status of harbor porpoises (*Phocoena phocoena*) has been reflected in several ways. In Canada, the species has been listed as a threatened species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In the United States, there was a petition to list harbor porpoises in the Gulf of Maine as a threatened species under the Endangered Species Act (NMFS 1993). In addition, in 1990 and 1991, the Scientific Committee of the International Whaling Commission (IWC) conducted a general review of the status of this species and recommended that bycatch be reduced in the western North Atlantic (IWC 1991, IWC 1992). In 1993, the IWC made a resolution that recommended additional data be collected and analyzed to assess the status of harbor porpoises in the North Atlantic and Baltic Sea (Annex A, Appendix 4).

In May 1992, a workshop was held in Woods Hole, Mass. during which available data and analyses were reviewed to determine the status of harbor porpoises in the western North Atlantic, and to identify research projects needed to improve an understanding of the status of this species. The 1992 workshop recommended (1) reducing bycatch from the Gulf of Maine/Bay of Fundy region, (2) collecting new data on bycatch and abundance for the U. S. Mid-Atlantic, Gulf of St. Lawrence, and Newfoundland regions, (3) obtaining more information to determine if the three putative sub-populations are separate, and (4) estimating potential population growth rates by incorporating the extent of uncertainty in life history parameters of harbor porpoises.

To address the 1992 workshop recommendations, another workshop was held February 23-25, 1994 in Woods Hole, Mass. Participants came from governmental and private agencies in the United States, Canada, and England (Appendix 1). Goals of this workshop were to (1) determine status of harbor porpoises in the western North Atlantic, (2) assess habitat requirements by examining factors correlated with harbor porpoise distribution and abundance, and (3) identify research needs for developing an improved understanding of the above topics (agenda in Appendix 2). Results presented represent the best judgement using all scientific information available at that time. During the workshop, 24 working papers were presented (Appendix 3). In this report working papers are referred to as WP##.

POPULATION STRUCTURE

Based on coincident summer distribution patterns, Gaskin (1984) suggested that harbor porpoises found in waters between North Carolina and Newfoundland consist of three more or less separate groups which he referred to as subpopulations. These were:

(1) eastern Newfoundland,
(2) Gulf of St. Lawrence, and
(3) Gulf of Maine, Bay of Fundy, and south western Scotian shelf.

The 1992 workshop concluded that there was no information available which could refute the discreteness of these proposed subpopulations. The rationale behind this decision was that groups could be sufficiently spatially distinct to justify management as separate "stocks" even though genetic exchange rates were high enough to eliminate genetic differences. This was deemed the conservative approach given the lack of information (NEFSC 1992).

In the 1994 workshop, recent available information on population structure of harbor porpoises in the entire North Atlantic was reviewed (WP22), but no new information was presented that could fully support or completely refute the existence of these three putative western North Atlantic sub-populations. However, new information from tagged harbor porpoises has demonstrated considerable mobility in animals within the Bay of Fundy (A. J. Read, unpubl. data). This information, coupled with the mtDNA RFLP study (Wang 1993) and the apparent large influx of animals into the Gulf of Maine in the summer of 1992 (WP1), decreased the workshop's confidence that the three putative western North Atlantic subpopulations are isolated from one another. Because of this uncertainty, several hypothetical population structures were constructed to investigate biological significance of bycatch (see Biological Significance section).

Techniques available to examine population structure were divided into two categories - those that might detect exchange of animals on an "ecological" time scale, and those that might detect exchange on an evolutionary time scale. The majority of the techniques that were discussed fell into the former category, while morphological and genetic techniques fell into the latter. Strengths and weaknesses of each technique were evaluated, as well as each technique's

Table 1. Fourteen techniques that could be used to examine population structure compared according to their usefulness for testing two population structure hypotheses, existence of samples for an oceanwide study, difficulty of analytical requirements, and the amount of methodology development required. N=no; Y=yes; H=high; M=medium; L=low; 1=H_1; 2=H_2; ?=unsure if this hypothesis can be tested with this method. See text for definition of hypotheses.

Method	**Test which Hypotheses**	**Sample Availability**	**Analytical Requirements**	**Development**
Movements (tagging)	1,2	N	H	H
		Biological		
Teeth characteristics	1,2	Y	M	M
Timing of breeding	1,2	Y	L	L
Life history parameters	1,2	Y	L	L
Parasites	1,2	N	L	L
		Chemical		
Organochlorines	1,2	N	H	L
Heavy metals	1,2	N	H	L
Isotopes	1,2	Y	M	L
Fatty acids	1,2	N	H	L
		Morphology		
Skull measurements	1	N	L	L
		Genetics		
mtDNA sequencing	1,2?	Y	H	L
Microsatellites	1,2?	Y	H	M
mtDNA RFLP		Y	M	L
Allozyme electrophoresis	1,2?	N	M	L

ability to test two hypotheses concerning population structure in the entire North Atlantic:

- H_1: there exists some number of subpopulations (14 or less) in the entire North Atlantic with small amounts of mixing among them, and
- H_2: there exists some smaller number of subpopulations in the entire North Atlantic with large amounts of mixing among them.

Finally, sample availability, analytical requirements and degree of required methodological development required were compared for each suggested technique (Table 1).

It was agreed that the degree of discreteness of subpopulations in the western North Atlantic was a pressing issue that required immediate attention, and that a wide-ranging program using a multidisciplinary approach was best suited to examine this question. Such an approach has been proposed for harbor porpoises in the entire North Atlantic (Appendix 4).

The workshop recommended that high priority be given to mtDNA sequencing and microsatellite DNA methods, that both of these methods be applied to the western North Atlantic harbor porpoises as soon as possible, and that an effort be made to determine if samples used in the completed mtDNA RFLP study could be used in these proposed studies. Furthermore, it was deemed important that samples be stratified not only by area but also by season so that within-area comparisons can be made. For instance, it was recommended that a study be conducted with non-summer Gulf of Maine samples to determine whether genetic composition has changed between years.

It was also concluded that studies of life history parameters and tooth ultrastructure characteristics of these three putative subpopulations should be conducted in parallel, and that the optimal situation would have these studies conducted on the same animals used in the genetic study. Finally, the workshop recommended that tagging studies continue, and that harbor porpoises in the Bay of Fundy be tagged

Table 2. Abundance estimates of harbor porpoises in the Gulf of Maine/Bay of Fundy region during 1991 and 1992, and percent of change between 1991 and 1992

Stratum	Abundance (%CV) 1991		Abundance (%CV) 1992		% Change 1991-1992
High density	16,900	(52)	24,500	(40)	+45
Intermediate density	16,900	(37)	31,900	(36)	+89
Low density	600	(16)	2,300	(29)	+283
Inshore	3,000	(51)	8,800	(28)	+193
Total	37,500	(29)	67,500	(23)	+80

during late fall to identify wintering grounds. The workshop noted that results of ongoing contaminant studies are expected to be completed soon, and that this information could provide insight into the population structure on an "ecological" time scale.

In conclusion, the workshop was not able to determine population structure of harbor porpoises in the western North Atlantic. Although this is the same conclusion made in 1992, new information now suggests that the three putative subpopulations may not be as discrete as previously believed.

RECOMMENDATIONS:

- Develop a multi-disciplinary approach to determine the uniqueness of the three putative subpopulations. Highest priority should be given to mtDNA sequencing and microsatellite DNA methods. Next in priority, but not in any particular order, are studies of tooth ultrastructure characteristics, life history parameter comparisons and individual movements.

- Conduct all studies with the same animals, if possible, even those used in the completed mtDNA RFLP study. Stratify samples not only by area but by season.

- Determine whether temporal differences in genetic composition can be detected in samples collected during non-summer months from the Gulf of Maine.

ABUNDANCE ESTIMATES

GULF OF MAINE/BAY OF FUNDY

In 1991 and 1992 shipboard surveys were conducted to estimate abundance of harbor porpoises in the Gulf of Maine/Bay of Fundy region. Both surveys were stratified first by water depth. The deep-water strata was further stratified by predicted relative density of harbor porpoises. This stratification scheme was applied only in data analysis; allocation of search effort to strata was approximately proportional to stratum area. There were minor differences in stratum boundaries between 1991 and 1992, and the exact pattern of transects within each stratum differed between years. The methods used for data collection were the same in the two years. A complete description of the survey methodology is given in WP1 and Palka (in press).

In both years, abundance estimates were much larger than previously thought (Polacheck 1989). Between the two years, the estimates differed by a factor of nearly two (Table 2), although this difference was not statistically significant. The workshop agreed that the 1991 and 1992 surveys provided the best estimate of abundance, but were concerned about the large difference between the two surveys. Factors other than a real change in abundance that might have contributed to the between-year difference that were considered were (1) survey crew capability and experience, (2) sea conditions, (3) interaction between local harbor porpoise movements and survey progression, and (4) effects of very-high-density areas which may have overloaded observers or biased the process of identifying duplicate sightings.

The 1991 estimated density did not change when the data were stratified by Beaufort sea state levels and when pooled over sea state levels (NEFSC 1992). In addition, the amount of time spent surveying during sea states 0 to 3 was similar in 1991 and 1992 (WP1). Thus, between-year differences in the sea state levels did not appear to have caused a between-year difference in abundance. In both years, survey progression was varied by leapfrogging survey blocks, so the chance of coincidence between local harbor porpoise movement and survey progression was small in both years.

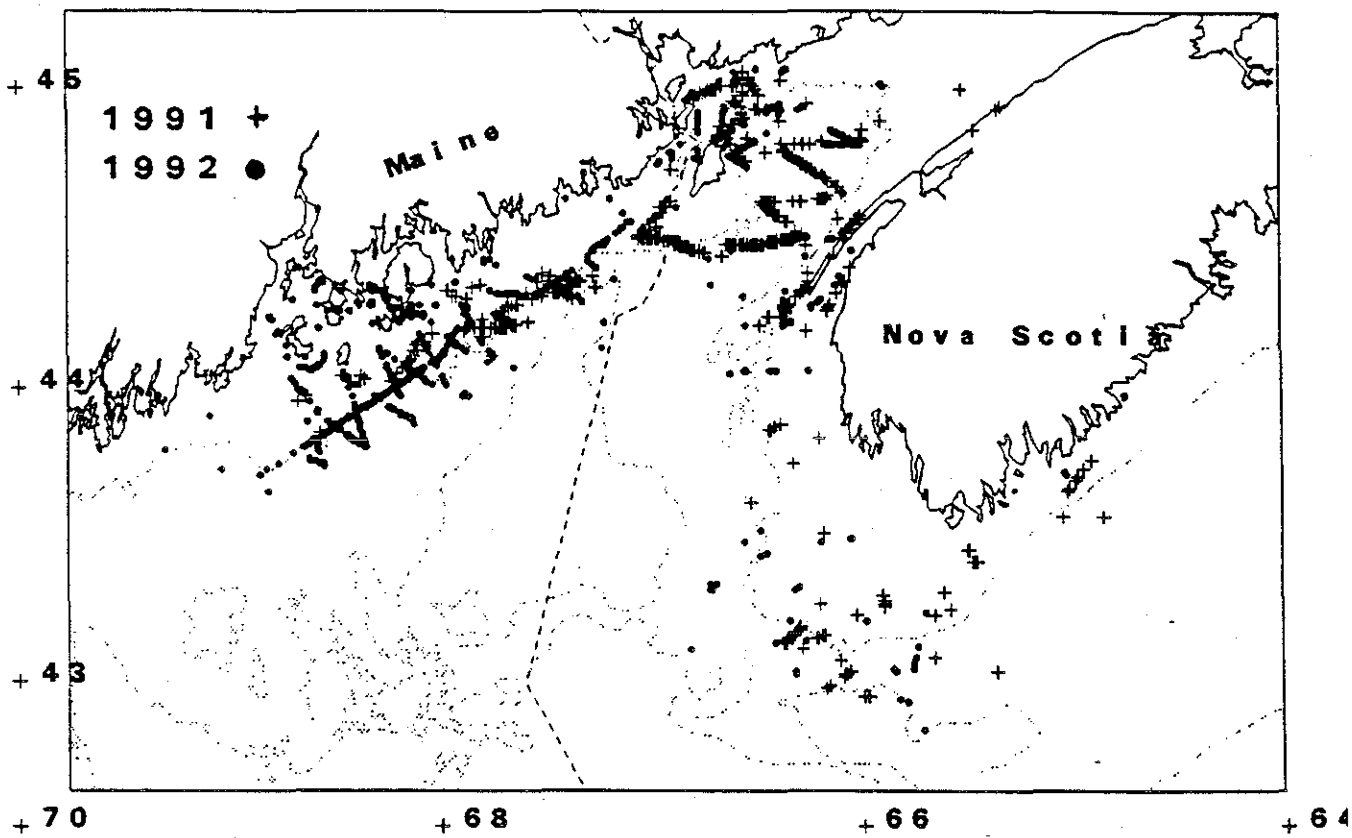

Figure 1. Location of harbor porpoise groups seen during the NMFS sighting surveys conducted in August of 1991 and 1992.

However, the workshop was not able to address concerns about effects of very-high-density areas, and about the initial capability and learning curves of survey crews, which might have differed between years. Thus, the workshop recommended that these factors be investigated further.

It was noted that during the high abundance year, 1992, there were more harbor porpoises in the southern portion of the study area than were seen during 1991 (Figure 1). It was also noted that migratory habits of harbor porpoises are poorly understood - in particular, it is unknown how consistent migratory habits are from year to year. In the Bay of Fundy area during the summer, WP11 demonstrated that there is year-to-year and even week-to-week variability in sighting rates of harbor porpoises seen during short transects. However, because there has been no series of comparable large-scale surveys (like that of the NMFS 1991 and 1992 surveys) against which to judge the single value of between-year difference, it is difficult to determine if the observed between-year difference was real or an artifact of the survey methodology.

Another survey was conducted in 1993, where the objective was to experimentally determine if some of the line transect sampling assumptions were valid. Consequently, the survey design differed from previous years. There was only one observation team that searched with the unaided eye (during 1991 and 1992 there were two such teams), there was an observation team that searched using 25x150 power binoculars, and in 1993 more effort was allocated to areas with high harbor porpoise densities. Despite these differences, the workshop noted that 1993 data could help assess the 1991-1992 variability by comparing, within a common region, 1993 density estimates to that from 1991 and 1992.

Most of the measured uncertainty in the abundance estimates was due to the highly variable sighting rate (number of animals per nautical mile; Table 3). The workshop recommended investigating methods used to estimate the uncertainty of the sighting rates which are more closely tailored to the survey design.

In conclusion, the workshop noted that differences between the 1991 and 1992 estimates, although not statistically significant, are large, and probably reflect a real change in numbers rather than sampling error or changes in observer performance. At the present time, not enough is known about seasonal movements of

Table 3. Mean group size and sighting rate per nautical mile of harbor porpoise groups from surveys in the Gulf of Maine/Bay of Fundy region during 1991 and 1992

	Sighting Rate (/nmi)		Number	Mean
	Mean	SD	of Groups	Group Size
1991	0.22	0.045	220	2.84
1992	0.38	0.067	202	2.80

this species to comment on where additional animals seen in 1992 might have come from.

RECOMMENDATIONS:

- Obtain three annual best density estimates for regions adequately covered during 1991, 1992 and 1993. Then reassess the 1991-1992 difference in light of differences between 1993 and previous years.

- Carry out confirmatory analyses to ensure that possible differences in measurement error have been examined, estimated, and bounded. In particular, investigate survey team learning curves, within-year time trends in observer performances and duplicate sighting rates and sighting drop-off rates in very-high-density areas.

- Review methods used for estimating sampling standard errors. In particular, determine adequacy of the bootstrap method and examine other methods that assume there is auto-correlation or linear trends in the sighting rates.

NOVA SCOTIA

No information was presented on abundance of harbor porpoises located from Halifax, Nova Scotia and eastward. The area west of Halifax was surveyed during the summer as part of the Gulf of Maine/Bay of Fundy surveys. To gather data from waters around Nova Scotia, a Department of Fisheries and Oceans (DFO) fleet observer program (10% coverage of domestic fleet and 100% coverage of foreign fleet) will be expanded to record locations of incidental sightings of harbor porpoises (J. Conway, pers. comm.).

GULF OF ST. LAWRENCE

No information was presented on abundance estimates from the Gulf of St Lawrence. However, an aerial survey of the region is being considered for 1995. It was recognized that careful planning and choice of equipment would be needed, so consultation and coordination between DFO and NMFS on aerial techniques was recommended. Because NMFS may be planning a joint aerial-shipboard survey for 1995 in the Gulf of Maine/Bay of Fundy area, it was recommended that the Gulf of Maine and Gulf of St. Lawrence be surveyed in synchrony.

NEWFOUNDLAND

No information on abundance estimates of harbor porpoises in Newfoundland waters is presently available and no future plans to obtain an estimate were presented. The workshop recommended that accurate abundance estimates be made for this area.

BYCATCH ESTIMATES

UNITS OF BYCATCH AND GEAR CHARACTERISTICS OF BYCATCH

It is desirable to identify a unit of effort that is correlated with bycatch levels so that bycatch per unit effort can be employed to estimate total incidental mortality of harbor porpoises. If found, this effort unit would be useful to examine whether characteristics of fishing gear are associated with catch rates. Examples of common units that have been discussed are tons of fish, number of trips, soak time, length of net, and number of hauls. For the Gulf of Maine sink gillnet fishery, bycatch rates of harbor porpoises were examined in relation to soak time and string length (WP4). A significant downward trend was demonstrated in bycatch with increased soak time. Total string length also had a significant effect on catch per unit of length, although there was no monotonic trend.

A similar study was performed with fishery data from the Gulf of St Lawrence (WP5). From a study of 22 Gaspé fishermen who set 2492 gillnets, 97.8% of the 401 bycaught harbor porpoises were caught in nets that targeted Atlantic cod, 99.5% were caught in nets set in water shallower than 200 m (100 fathoms), and 70% were caught in nets with 6 to 6.5 inch mesh. The interactions between these factors were not investigated, so no causal inference can be drawn. It was noted that two fishermen caught 78% of the harbor porpoises. One of these fishermen used a net that was twice as long as those used by other fishermen in the same area. The other fisherman caught 159 harbor porpoises during a limited time, mostly in 2 out of the 16 weeks observed.

In conclusion, neither soak time nor net length was recommended as a measure of effort. Thus, a unit of effort better than that suggested in the past (tons of fish landed) has not been determined.

RECOMMENDATIONS:

- Investigate correlations of soak time and net length with different fishing strategies for various target species in different areas and seasons.

GULF OF MAINE

Estimates of total bycatch in the Gulf of Maine sink gillnet fishery for 1990 to 1992 were presented in WP1 and WP2. Information from 1993 was summarized verbally. Estimates of bycatch per trip were derived separately for the northern and southern Gulf of Maine for each year between 1989 and 1993. In the northern Gulf of Maine, summer and fall bycatch rates remained relatively unchanged between 1991 and 1993. In the southern Gulf of Maine, harbor porpoise bycatch rates were near zero in the summer, but were high in fall and winter. The area immediately south of Cape Cod was included in the 1992 bycatch estimate after these fishing vessels were included in the sea sampling program. The estimated total bycatch of harbor porpoises in the entire Gulf of Maine (north and south combined) decreased over the period from 1990 to 1992. The 1993 bycatch data were incomplete at the time of the workshop.

Discussion of sources of bias in the bycatch estimation process included: harbor porpoises falling out of the net before being counted during "off-watch" hauls, distraction by other observer duties, sampling representativeness, and completeness of the weighout database (WP3). The issue of fallout from nets was discussed because in the 1992 workshop concerns were voiced that observers who were not totally focused on the incoming net (*i.e.* when tending to other assigned duties) might miss harbor porpoises that fall out of the net before it comes on deck. To investigate this potential problem, beginning in May 1992, sea sampler observers on Gulf of Maine vessels were instructed to watch the net even before it comes on board, to document when animals fall out of the net, to determine to what extent the animals were entangled in the net, and, if time permits, to record information on discarded fish species. This exercise showed 37% of the observed bycaught animals did not come aboard.

The investigation led to a more in-depth investigation into bycatch rates during "on-watch" and "off-watch" hauls. "On-watch" hauls are those hauls during which observers were directed to watch the net as it comes out of the water. "Off-watch" hauls are those hauls during which observers were directed to perform fish assessment tasks. Therefore, information on bycaught harbor porpoises was recorded only from animals that came onboard or were identified by a crew member. Thus, during "off-watch" hauls there was a possibility that some bycaught harbor porpoises were missed. "Off-watch" harbor porpoise bycatch rates per haul and per ton of total fish landed were consistently lower than "on-watch" bycatch rates, although the differences were not statistically significant. However, it was noted that the statistical test used, Chi-square, had low statistical power to distinguish differences. The workshop concluded that the difference in bycatch rates indicated that some harbor porpoises that fell out of the net may have been missed, and therefore, past estimates of bycatch rates (WP1 and WP2) were likely biased downward. The workshop recommended that total bycatch estimates be recalculated using only data collected during "on-watch" hauls. It was recognized that this would reduce the effective sample size by about half and so increase the coefficient of variation of the total bycatch estimates. Recommendations were made on how to continue this investigation.

The 1992 workshop recommended investigating whether vessels were sampled in an unbiased manner. During the 1994 workshop, it was demonstrated that the number of sampled trips was proportional to the total number of trips that occurred in the fishery according to the weighout data. It was demonstrated that some ports were not sampled in proportion to the number of trips originating from that port, however, the effect of this bias on the total bycatch estimate was small (WP1). The workshop concluded that there was no evidence to indicate that the sea sampling data were biased to a large degree. However, additional investigations were recommended.

The 1992 workshop recommended that the quality of the weighout data be investigated; in particular, determine if all gillnet vessels were included and how much of the landings may of been missed. To address the first issue, in 1992 the NMFS/NEFSC conducted a survey of all fisherman to determine who was fishing, how much, at what times of the year, and with what type of gear (WP19). From this survey, it was estimated that there were between 287 and 331 gillnet vessels fishing in the waters from Maine to Rhode Island. An additional 187 vessels were found to occasionally fish with gillnets for bait or personal use; these vessels were not investigated further. Of the 287 confirmed gillnet vessels, 16% to 30% were full-time gillnetters. Of the part-time gillnetters, lobstering was the primary alternative activity (41%), tuna fishing was second (31%) and trawling was third (12%). Recently, representatives from various ports and NMFS personnel reviewed all vessels identified in the survey and compared them to those vessels found in the weighout database. It was found that 26 vessels identified as gillnetters in the weighout database were actually draggers, and an additional 15 vessels had coding errors that caused gillnet landings to be associated with them instead of the correct gillnet vessel. There are still 44 vessels that need to be checked or surveyed. It was noted that vessels not coded as gillnet vessels were not checked to determine if that vessel should be coded as a gillnet vessel. From these results, the workshop concluded that there is no current evidence of a large percentage of vessels missing from the database.

To estimate the landings that may be missing from the weighout database, tonnage vessels were tracked among the weighout, Marine Mammal Exemption Program Logbooks, and the survey just discussed. The lowest common denominator of effort between databases was a vessel-month. Because of many potential problems, the workshop agreed that an accurate estimate of missing landings could not be made using this method. It was noted that if mandatory vessel and dealer reporting begins in March 1994, then it may not be necessary to continue this investigation, assuming that reporting is accurate.

In conclusion, examination revealed that the sea sampling scheme and weighout database were not as biased as was thought in 1992. After discussing other possible biases of the bycatch estimate from the Gulf of Maine gillnet fishery, the workshop concluded that previously reported bycatch estimates represent a minimum point estimate, which has known, and unmeasured negative biases; and that reported confidence intervals were too small by an unknown amount. In addition, to account for the potentially large bias due to on- and off-watch differences, total bycatch estimates from the Gulf of Maine should be recalculated.

RECOMMENDATIONS:

- Investigate whether sampled fishing vessels are a biased sample by comparing the distribution of bycatch rates from vessels that were sampled many times to the bycatch rate distribution from vessels that were infrequently sampled. Also, perform the above analysis using fish landings instead of trips, to be consistent with the bycatch estimation method.

- Determine the accuracy of landing totals and number of trips in the weighout database.

- Recalculate bycatch estimates using only data collected during "on-watch" hauls to account for the possible bias of harbor porpoises falling out of the net. In addition:

  (1) determine if the rule for being "on-watch" was followed consistently,
  (2) evaluate the difference between "on-watch" and "off-watch" bycatch rates by using more powerful statistical tests,
  (3) determine if there are time/area correlations with the on- and off-watch bycatch rates,
  (4) develop a method to correct for "off-watch" unrecorded fallouts so that all of the data can be used in the estimation of total bycatch.

MID-ATLANTIC COAST OF THE UNITED STATES

Bycatch in the Mid-Atlantic region of the eastern United States coast occurs, but the extent is unknown. Observer coverage through the sea sampling program has increased on gillnet vessels operating in Massachusetts waters south of Cape Cod and in Rhode Island waters. Harbor porpoise bycatch has been observed in this area and was included in the 1992 bycatch estimates for the Gulf of Maine sink-gillnet fishery.

In the past, evidence for harbor porpoise bycatch in the Mid-Atlantic region was twofold. First, stranded harbor porpoises had cuts and body damage suggesting net markings; and second, timing of these strandings was often associated with known coastal gillnet fishing activities (Haley and Read 1993). For example, between 23 February and 15 May, 1993, 50 harbor porpoise strandings were reported from New York to North Carolina. Many of these strandings were reported from Virginia in April. Five of the eight carcasses and fifteen heads that were examined showed signs of human interactions (net markings on skin and missing flippers or flukes). Conditions of the remaining harbor porpoises prevented determination of the cause of death.

To document possible fishery-harbor porpoise interactions, in July 1993 the sea sampling program was expanded to Virginia. Between July 1993 and February 1994, 57 trips were observed. To date there have been no observed takes of harbor porpoises in these trips. However, at this time, distribution of observer effort in Mid-Atlantic waters has not included the period of known strandings, which occurred primarily from mid-March to May. Thus, as observer effort in 1994 continues in the Mid-Atlantic, a more complete picture of fishery-harbor porpoise interactions is expected to emerge.

The combined information suggests that in Mid-Atlantic waters, harbor porpoises experience a known, but not yet quantified fisheries related mortality. The fisheries of primary concern are coastal gillnet fisheries that begin in early February and continue through May, and extend from New Jersey to, at least, North Carolina.

A brief description of fisheries that occur south of Cape Cod is found in WP23. In summary, gillnet activity in Rhode Island has increased substantially in the past two years as new vessels have entered the fishery and lobster vessels have rigged over to target blackfish, monkfish, and dogfish. The entire fishery is principally active from April through October and there are few area, mesh, or time restrictions. Groundfish/dogfish vessels, which fish from November through May, are classified as a Category I fishery by NMFS, and observer coverage is required (approximately 10% observer coverage at this time).

The gillnet fishery in Connecticut is a small-scale fishery that requires participating fishermen to submit annual catch reports. The majority of gillnetters target menhaden and baitfish for personal use in lobster pots, using gillnets that range between 25 and 500 ft in length. Other fish targeted with gillnets are American shad, smelt, tomcod, perch, and catfish. Mesh size restrictions are imposed on fisheries targeting some fish species.

New York has little seasonal restrictions, gear type information, or fishery effort information for the 293 gillnetters licensed in New York. Logbooks are not required.

In New Jersey, an unknown number of gillnet vessels target weakfish from the early fall to early spring. American shad are targeted in the late spring to summer (March and April are peak months). A shark and Atlantic sturgeon gillnet fishery occurs in the spring. Restrictions on length of nets and mesh sizes are imposed at various times of the year for different fisheries.

In Delaware, the gillnet fishery (both fixed and drift) has the largest number of licenses relative to all other fisheries in that state. The majority of fishing activity occurs inside Delaware Bay where fixed gillnets target American shad in April and weakfish in May. Fixed gillnets are prohibited from May 11 through the end of September, when only drift gillnets, largely targeting weakfish, sea trout and bluefish, are permitted to fish with a maximum of 3000 ft of net per vessel.

Based on commercial landings data received from Maryland, December through April appear to be the peak months for the 567 gillnetters registered to operate in Maryland waters. Gillnetting targets American shad, weakfish, spot, croaker, striped bass, and white perch. The use of gillnets in the Chesapeake Bay is restricted to tended drift gillnets and no gillnetting can occur in the bay during summer.

Approximately 5300 gillnet vessels are registered to fish in Virginia waters. Approximately 100 to 200 fishermen fish for American shad from March 15 through April 30. Gillnets accounted for nearly all of the commercial landings in Virginia in 1992, and approximately two-thirds of the landed value.

North Carolina's multispecies gillnet fishery (both drift nets and anchored gillnets) targets weakfish, striped bass, flounders, bluefish, and Atlantic croaker and is active from November through April. Little is known of the level of fishing activity. A swordfish drift gillnet fishery occurs in Mid-Atlantic waters seasonally, usually near the continental shelf break. Several species of cetaceans have been observed taken in this fishery, including on one occasion, a harbor porpoise.

In conclusion, bycatch of harbor porpoises in the United States Mid-Atlantic region is known to exist, although the extent is unknown.

RECOMMENDATIONS:

- Expand the sea sampling observer effort to the area from Cape Cod to North Carolina at a level comparable to that in the Gulf of Maine (5 to 10% of gillnet effort). This coverage should occur not only at a time when harbor porpoise takes have been inferred from stranding data (February through April), but continue throughout the year (as already started by the sea sampling program).

CANADA, IN GENERAL

With the downturn in the groundfish fisheries in all of Atlantic Canada, the level of fishing effort during 1994 is unknown. Fisheries that have been closed for 1994, either in whole or in part include: (1) Georges Bank for cod and haddock, closed until June 1 1994, (2) NAFO subareas 4TVW (closed January to April for cod) and 4VW (closed May to December for cod), both areas are near Cape Breton, (3) Gulf of St Lawrence closed all year to cod fishing, (4) NAFO subarea 2J3KL, which covers Newfoundland, is closed all year for cod fishing, and (5) NAFO subarea 4TVW is closed all year for targeting haddock, but haddock bycatch is allowed. Fisheries that will remain open that have reduced TACs (Total Allowable Catches) are NAFO subarea 4X and 5Z for cod and haddock and 4VWX5 for pollock. The workshop noted that even though some fisheries will be closed, there is the possibility that some fishing effort will be shifted to open fisheries/ areas. Thus, the effect of the changed fishing effort on harbor porpoise bycatch is unknown.

BAY OF FUNDY

Preliminary results of a Canadian study to find methods to reduce harbor porpoise bycatch in demersal gillnets fished in the Bay of Fundy were presented orally. This voluntary study was conducted from July 30 to September 10, 1993 and employed 4 observers who recorded data from 15 fishermen during 65 trips. Results indicated that more harbor porpoises were caught per trip in nets set in inshore waters than in offshore waters. Harbor porpoise catches were greater in sets of longer duration (*e.g.* 72 hrs), and in sets that contained herring and dogfish. Gear configurations were similar among the fishermen. Differences in lead line (single versus double) and anchor weights were not associated with harbor porpoise bycatch rates.

In conclusion, the workshop was pleased that observer coverage has been initiated in this area and recommended that total bycatch estimates be made for the Bay of Fundy.

GULF OF ST. LAWRENCE

In 1989 and 1990, mail surveys completed by fisherman were used to estimate bycatch of harbor porpoises in the Gulf of St. Lawrence. Fontaine *et al.* (in press) estimated that about 1900 animals per year were caught. However, with only a 33% and 18% return rate of the surveys mailed in 1989 and 1990, respectively, the reliability of the bycatch estimates were questioned by the workshop.

Another study was performed from May through August 1992 with 22 fishermen in several fishing areas. The purpose was not to estimate total bycatch, but to determine if there were patterns of fishing habits that correlated with bycatch rates (WP5). In this small subset of the fishery, there were 401 harbor porpoises caught in 2492 gillnet hauls [*i.e.*, 0.16 harbor porpoises caught per haul. Other ways to look at the bycatch rate are: 1.48 harbor porpoises were caught per (10^6 m of net x hour set), or 1.34 harbor porpoises were caught per ton of landings.

RECOMMENDATIONS:

- Use results from the 1992 study to evaluate if the previous mail survey is a realistic way to estimate total bycatch of harbor porpoises.
- Describe gear characteristics and landings for the entire gillnet fleet.
- Make more recent total bycatch estimates for the Gulf of St. Lawrence region.

NEWFOUNDLAND

No information on bycatch of harbor porpoises in Newfoundland waters is known, other than that reported at the 1992 workshop. Because of many problems already discussed during the 1992 workshop, observed bycatch rates were not scaled to estimates of total bycatch (NEFSC 1992). Therefore, the 1994 workshop recommended that estimates of total bycatch of harbor porpoises be made for this area.

OBTAINING ROUGH ESTIMATES OF HARBOR PORPOISE BYCATCH IN AREAS WITH LIMITED OBSERVATIONS

There are several areas in the western North Atlantic where anecdotal or limited quantitative data indicate the existence of a fishery bycatch of harbor porpoises. Harbor porpoise bycatch for the U. S. part of the Gulf of Maine has been estimated for the last four years. To obtain a wider picture of fishery interactions with harbor porpoises of the western North Atlantic, even rough estimates of total bycatch from other areas such as the U. S. Mid-Atlantic coast, Bay of Fundy, Gulf of St. Lawrence, and Newfoundland are desirable. The workshop recommended that a procedure be outlined for making rough estimates of bycatch in the absence of more detailed data. For all areas, the workshop strongly encouraged that the collection and analysis of detailed harbor porpoise bycatch information be made from as many fisheries as possible. It was emphasized that rough estimates obtained from the calculations described next are only intended for use in scientific discussions of the status of harbor porpoises, **not** as direct advice to managers.

For fisheries where there is at least anecdotal evidence that bycatch occurs, it was suggested that rough estimates be made of the total bycatch by using whatever limited data there is on bycatch rates within the area or from adjacent areas where similar fisheries operate. Harbor porpoise bycatch per ton of target species of fish landed within each quarter (preferably month) of the year is one appropriate measure for such extrapolations. Care should be taken that target species for the fishery are known precisely, since landings are used as a proxy for fishing effort in this analysis. Also, because of changes in fish abundance from year to year, bycatch rates per ton should not be averages over years or taken from a previous year's sampling program.

To calculate rough estimates of harbor porpoise bycatch in a particular area, landings data by quarter (preferably month) and by port or fishing ground for that area are needed. These landings are applied to a distribution of bycatch rates that were measured during a similar time period from another area which has a similar fishery. For example, to obtain rough estimates of harbor porpoise bycatch in the Bay of Fundy, the distribution of bycatch rates per ton of cod landed in the northern Gulf of Maine (north of Port Clyde, Maine) by quarter would be applied to landings of cod by quarter from the Bay of Fundy. The result is a distribution of bycatch estimates for the Bay of Fundy. A similar exercise with other target species, such as pollock, may provide an estimate of uncertainty in the rough estimate of bycatch.

The assumptions made in this exercise are:

(1) harbor porpoise population in the estimation area (*e.g.* Bay of Fundy in the example) is in synchrony with the data area (*e.g.* northern Gulf of Maine in the example). That is, migration of harbor porpoises into the two areas occurs at the same time.
(2) bycatch rates (harbor porpoise/ton of target species landed) are appropriate for the estimation area and that landings of the target species of fish are related to fishing effort.
(3) landings data are sufficiently accurate.
(4) harbor porpoise density in the estimation and data area are roughly similar.

Wherever possible, tests of the predictive power of this analysis should be performed. For example, if some limited data are available from the estimation area, estimates based on these data should be compared with the distribution of estimates based on the above rough estimation procedure.

In conclusion, the workshop suggested a methodology to be used to obtain rough estimates of harbor porpoise bycatch from areas with limited observations. However, estimates made using this method should be supplanted by estimates made using detailed data of observed bycatch rates when such data become available.

RECOMMENDATIONS:

- Calculate rough bycatch estimates for summer fisheries in the Bay of Fundy and Gulf of St. Lawrence and winter fisheries in the Mid-Atlantic, if data are available. When possible, assess if assumptions are valid.

POPULATION GROWTH RATE

Estimates of population growth rate are important because the biological significance of bycatch mortality rates can be made by comparing population mortality rates to actual population growth rates (IWC 1991). At the 1992 workshop, it was concluded that lack of data precluded estimating the *actual* population growth rate, however, the *potential* population growth rate could be estimated. Thus, a comparison between the potential population growth rate and population mortality rate could serve as a bound on the biological significance. However, even estimating the potential growth rate for harbor porpoises is difficult because of the limited data available. There are some data on age-specific reproductive output, but none are available on age-specific mortality. Two attempts had been made previously (Barlow and Boveng 1991, Woodley and Read 1991) to calculate potential population growth rates using survivorship information from other species that act as model life tables. These estimates had been used by the IWC (1991). However at that time, there was no way to quantify the uncertainty of these estimates. To address these uncertainties, the 1992 workshop proposed a method that estimates the potential population growth rate and quantifies the uncertainty about this estimate. This was developed in WP10A and WP10B, which describe the general method and its application to harbor porpoises, respectively.

In general, the population growth rate (λ) is determined from a population projection matrix, whose elements are age- or stage-specific rates of survival, reproduction, and sometimes growth. These rates in turn are determined by a set of parameters *(e.g.*, mortality rates, parameters of survival functions, pregnancy rates, *etc.*). If the uncertainty in these underlying parameters can be characterized by a probability distribution, then resulting uncertainty in the population growth rate can be determined by sampling that distribution repeatedly, generating projection matrices and calculating population growth rates.

In the case of harbor porpoises, there are little data (especially on survival) and lots of uncertainty. In this analysis, reproductive parameters and their uncertainties were obtained from distributions of age-specific lactation frequency and age at sexual maturity (Read 1990; Read and Gaskin 1988). In the absence of harbor porpoise survival data, a set of model life tables were obtained for comparable species (large, long-living mammals producing single offspring: African buffalo, Dall sheep, elephant, impala, orca, ringed seal, wildebeest, and zebra). The model life tables were rescaled so that age at sexual maturity of the model species matched that of the harbor porpoise.

A "synthetic" harbor porpoise life table was then created as a weighted mean of the rescaled life tables, where the weights were uniformly distributed over the set of all weights summing to one. A population projection matrix was calculated from the synthetic life table and observed maternity function, then λ was calculated as the maximum eigenvalue of the population matrix. This protocol was repeated to generate 6000 realizations of the harbor porpoise rate of increase estimate (Figure 2).

The distribution of λ reflects the following sources of uncertainty in vital rates of harbor porpoises:

- uncertainty in age at sexual maturity of harbor porpoises as reflected in the maturity ogives in Read and Gaskin (1988);
- uncertainty in age at sexual maturity of each model species, as reflected in age-specific reproductive information accompanying each life table;
- uncertainty in age-specific reproductive output of harbor porpoises, as reflected in lactation frequency data of Read (1990); and
- uncertainty in the harbor porpoise life table, as reflected in the range of life tables for large mammals with single offspring.

The resulting distribution of λ and its percentiles suggested that, given the very considerable uncertainty in our knowledge of harbor porpoise vital rates, it is unlikely that the potential growth rate is greater than about $\lambda = 1.1$ (*i.e.*, 10% growth per year). If the best estimate of the potential growth rate is represented by the median of the distribution, then the best estimate is approximately 4%. It is not known if the best estimate is the median of the distribution.

For comparison, the estimate of Barlow and Boveng ($\lambda = 1.094$), obtained using a rescaled human life table, is approximately the 90th percentile of the above distribution. The estimate of Woodley and Read (λ is nearly equal to 1.04) is close to the median of the distribution.

The significance of values of λ less than 1.0 was questioned. Since the harbor porpoise is not extinct, the potential rate of increase must be greater than 1. But, about 30% of values in the Monte Carlo simulations were less than 1. This is not unexpected; it simply means that, within the possibilities of life history patterns as defined by our current state of ignorance, there are some that are infeasible for harbor porpoise. Put another way, given our current state of knowledge, these values can not be ruled out, even though it is known that these values are infeasible. There was discussion, but no agreement

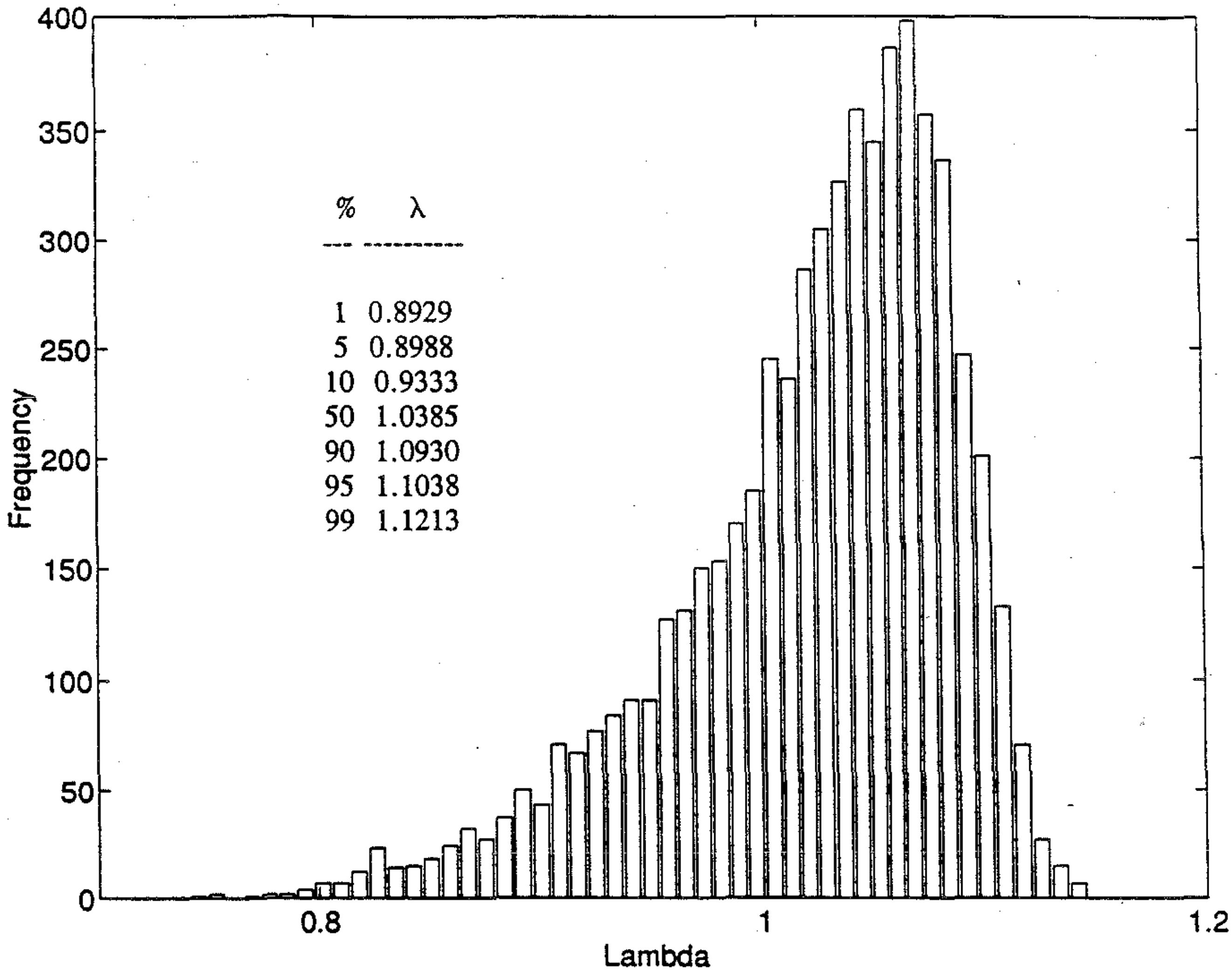

Figure 2. Harbor porpoise potential rate of increase, N=6000.

about whether the distribution should be truncated at $\lambda = 1$, and rescaled to take advantage of our additional knowledge that the harbor porpoise **is** able to maintain itself.

Alternative scaling of model life tables were discussed. The present analysis involved a rescaling of age in the model life tables. There was discussion as to whether this should be treated as a rescaling of time as well, and applied to reproductive rates. In fact, this is already taken into account, because rescaling the life table also rescales the inter-birth interval, which itself scales roughly in proportion to age of sexual maturity. The workshop recommended that alternative scalings be investigated further.

Because of absence of information to the contrary, the sampling of survivorship and fecundity schedules are assumed independent. However, in reality the two are correlated. The lack of this correlation is one explanation for values of $\lambda < 1$.

The distribution of λ obtained from this exercise characterized the uncertainty in the present information on vital rates. There are sticky philosophical problems involved in interpreting this uncertainty as a probability. A Bayesian approach might interpret this distribution as giving the probability of a specific value of the real world harbor porpoise rate of increase. A classical approach might interpret the distribution as one trial of some unknown distribution, and thus not provide a probability value. The workshop made no recommendation as to which approach was appropriate, however, they did recommend that care be taken when interpreting this distribution.

In conclusion, a model life-table method that was developed to incorporate uncertainty about many aspects of harbor porpoise vital rates led to the conclusion that it is highly unlikely that the potential growth rate of harbor porpoises exceed 10% per year and, if the median of the uncertainty distribution is the best estimate, then 4% per year is the best estimate of the potential population growth rate.

RECOMMENDATIONS:

- Test the model life-table method by using it to predict a life table for a species (*e.g.*, orca) for which the life table is already known.
- Investigate alternative rescalings of model life tables to take reproductive rates into account.
- Try to empirically characterize correlations between survivorship and fecundity in the model life tables.
- Apply variance decomposition methods to the output distribution of λ to see which sources of parameter uncertainty contributed the most uncertainty.

HABITAT DESCRIPTION

The definition of habitat can be interpreted in many ways, so for this purpose "habitat" has been defined as those physical, biological, and anthropogenic factors that influence distribution and abundance of harbor porpoises. Because it is difficult to demonstrate that a factor causes an observed distribution pattern, correlations between factors and harbor porpoise distribution have been investigated. As a result, a list of factors that were believed to be correlated with harbor porpoise abundance and distribution was compiled (Table 4). For each factor, WP21 summarized data that supported the correlations. In addition, it was noted whether there were sufficient data available to determine if a factor was correlated with harbor porpoise distribution and abundance and what future research would be needed to investigate the hypothesized correlation.

Because of limited data, the description of harbor porpoise habitat was limited to a well-studied area where the density of harbor porpoises was known to be high: parts of the Gulf of Maine/lower Bay of Fundy western Scotia shelf region (GOM/BOF) during the summer. Specifically, this region is north of 43°30' N on the Maine coast, north of 42°30' N off Nova Scotia, south of 45°10' N in the Bay of Fundy, east of the U. S. Atlantic coastline, west of 65°00' W along Nova Scotia and within 100 fathoms of depth (Figure 1). Summer was defined as July through September.

Table 4. List of factors that were believed to be correlated with the distribution of harbor porpoises found in the Gulf of Maine / lower Bay of Fundy / western Scotian shelf region during the summer months of July to August. In the second column, it is indicated whether there was sufficient data to determine if a correlation exists. The last column indicates whether the values of the factor are fixed in space and time. Y=yes; N=no.

Factor	Sufficient Data?	Fixed
Factor most likely correlated with observed distribution		
Surface temperature	Y	N
Depth	Y	Y
Vertical mixing	Y	Y
Topography	Y	Y
Herring	N	N
Silver hake	N	N
Factor may be correlated with distribution		
Predators	N	N
Maternal requirements	N	N
Human disturbance	N	N
Commercial fishing	N	N
Other prey species	N	N
Competitors	N	N

Data used to investigate correlations between harbor porpoise density and various factors were described in previously published articles, WP12, WP13, WP14, WP16, and WP17. The data in the working papers were collected during Manomet Bird Observatory opportunistic sighting surveys (1980-1986), NMFS sighting surveys conducted by ship and airplane (1991-1993), U. S. sea sampling observer program (1990-1993), and NMFS bottom trawl surveys (1982-1993).

Physical factors thought to be correlated with harbor porpoise distribution included water temperature, water depth, vertical mixing, and bottom topography. Biological factors included distribution of primary prey species (herring and silver hake), predators, maternal requirements (both spatial and nutritional), other prey species, and potential competitors. Anthropogenic factors included human disturbance and commercial fishing operations (Table 4). The only factors thought to have sufficient data to determine the degree of correlation were water temperature, depth, vertical mixing, and bottom topography.

Harbor porpoise distribution may be influenced by water temperature, both at the surface and below. During the summer, GOM/BOF harbor porpoises are found in waters that are from 7 to 15°C, but mostly are 11 to 14°C (Gaskin 1992; WP16; WP17). Although there is a correlation between temperature and distribution, the reason is unclear. One possible explanation is that water temperature may be correlated with distributions of herring or other prey species.

Most harbor porpoises have been seen in relatively shallow waters, less than 100 fathoms in depth. (Gaskin 1984; WP17). Using Generalized Additive Models (GAMs), sighting rates were demonstrated to be highest in waters that were between 20 and 70 fathoms deep. During 1993 only, sighting rates were also high in waters that were 70 to 110 fathoms deep. Though harbor porpoises are often found in shallow waters, one animal was documented diving to 124 fathoms, however, the average of 254 hr of recorded dives was 13.7 ± 16.4 fathoms (WP15).

In some areas of the Bay of Fundy, fine-scale relative abundance of harbor porpoises were positively correlated with the presence of vertically mixed water, which may of been caused by tidal mixing or sharp bottom slopes (Watts and Gaskin 1985). It has been hypothesized that this type of water is characteristic of "upwelling," which provides a rich source of nutrients, copepods and herring, a harbor porpoise prey species (Smith and Gaskin 1983; Sutcliffe and Brodie 1977).

Fine-scale temporal and spatial distribution of harbor porpoises is correlated, although not strongly, with the distribution of herring (Watts and Gaskin 1985). Lines of evidence for this correlation are (1) harbor porpoise sighting rates from marine mammal surveys increased as the amount of herring on NMFS trawl surveys increased (WP14, WP17), (2) herring and silver hake were the most prevalent prey species in stomachs of harbor porpoises caught in the Gulf of Maine during all seasons (WP12), and (3) harbor porpoise sighting rates in the west side of Penobscot Bay (which had many fish targets) were greater than rates in the east side of the bay (which had few fish targets) (WP16). For comparison, 60 harbor porpoises caught in Atlantic cod nets in the Gulf of St. Lawrence had a preponderance of herring and capelin in their stomachs (WP5). In contrast, stomach contents of 247 harbor porpoises from Norwegian, Swedish, and Danish waters revealed that harbor porpoises taken from deeper waters (> 100 fathoms) generally ate pelagic and mesopelagic fish (for example, herring) while those harbor porpoises taken from shallower waters ate a larger percentage of benthic prey species (WP18).

Along the United States Atlantic coastline, herring populations are increasing (NEFSC 1993), which may be reflected in an increase in the distribution of herring in the summer. The effect of such a range expansion on harbor porpoise habitat is unknown. In the area immediately south of the known harbor porpoise summer habitat, there are concentrations of herring but very few harbor porpoises. The workshop was unable to explain why this has occurred. Possible hypotheses were: (1) since water temperature in the outside area (16 to 18°C) was higher than that found inside the usual habitat, the temperature range in the outside area may be too high for harbor porpoises; (2) tradition, that is, harbor porpoises return to the same areas year after year, even if other areas are just as good; and (3) herring distribution has only recently expanded to this outside area, and the harbor porpoise distribution has lagged behind.

Harbor porpoise distribution may be related to the distribution of predators, particularly, mako and white sharks. There have been documented cases of these shark species eating harbor porpoises (Arnold 1992). Because shark populations have decreased over the last 10 years (FMP 1993), it was hypothesized that harbor porpoises increased their range and/or density (WP13). There is no direct evidence for this hypothesis.

Another factor that may be correlated with harbor porpoise distribution, but for which little information is available, is maternal requirements, such as nutritional requirements and the need for protected areas to raise calves. Such areas have not been demonstrated so far (WP16) and nutritional requirements of lactating females are not known.

Human disturbance could also affect the size and shape of the harbor porpoise habitat. For example, it has been noted that relative abundance of harbor porpoises decreased markedly after salmon pens were constructed in the lower Bay of Fundy (Gaskin 1992). Other factors such as pollution and coastal development may be important (Gaskin 1992), but evidence was not available to support or deny this hypothesis.

Distribution and abundance of other prey species could also be correlated to harbor porpoise abundance and distribution. It is not known to where harbor porpoises migrate in the winter and what they eat during this time. Because a single harbor porpoise that was caught in a swordfish drift gillnet off Cape Hatteras in February 1993 had a stomach full of myctophids, a previously unknown prey species (A.J. Read, unpubl. data), there may be other important prey species which are not known. In addition, harbor porpoises caught in gillnets may eat a different diet than those harbor porpoises that are not caught in gillnets. Thus, even for the Gulf of Maine, where current knowledge of prey species comes from harbor porpoises caught in gillnets, it is possible that other important prey of some harbor porpoises may still be unknown.

On a theoretical basis, it is possible that in some areas of potential harbor porpoise habitat, harbor porpoises may be excluded because of the presence of competitor species. Suggested competitors were dogfish, cod, and pollock. There is no evidence for this hypothesis.

The workshop noted that a potential problem with the data/methods used to investigate these correlations is that NMFS bottom trawl crude indices of relative abundance of prey species were used. It would be desirable to use biomass or corrected abundance estimates in the correlations. Although for some species these estimates are made for the entire Gulf of Maine, a smaller scale estimate would be desirable for the correlations. In addition, the NMFS trawl database does not include fish found on the Scotian shelf. To complete the picture, the workshop recommended obtaining research survey data on prey species from the Scotian shelf.

This discussion was limited to only the summer habitat of harbor porpoises found in the Gulf of Maine / lower Bay of Fundy / western Scotian shelf region because of lack of information about the distribution of harbor porpoises outside this area during other seasons. The workshop recommended that more should be learned about the habitat of harbor porpoises during times other than the summer, especially during the time when mating occurs (June). To obtain more information about harbor porpoises on the Scotian slope, Canadian observers on vessels fishing the Scotian slope area will be asked to record harbor porpoise sightings. To obtain more information about the United States Mid-Atlantic region, several recommendations were made to use existing data to determine potential winter grounds, as detailed next.

In conclusion, data needed to describe the entire harbor porpoise habitat were unavailable. The workshop concluded that there are data which suggest that factors such as temperature, depth, vertical mixing, and prey species distributions are correlated to the summer distribution of harbor porpoises found in the Gulf of Maine / lower Bay of Fundy / western Scotian shelf region. Other factors that may be correlated with summer distributions, but for which data are lacking, include bottom topography, predators, competitors, maternal requirements, human disturbances, and commercial fishing activities.

RECOMMENDATIONS:

- Learn more about correlations between sea surface temperature and harbor porpoise distribution by describing the worldwide temperature distribution of waters with harbor porpoises. In addition, water temperature at various depths should be correlated with sighting rates of harbor porpoises and distributions of herring.
- Investigate correlations between harbor porpoise sighting rates and changes in topography (slope steepness and physical properties, such as fronts).
- Investigate correlations between harbor porpoises and prey distributions, in particular, vertical and horizontal distributions. In addition, investigate trophic interactions, and habitat requirements of prey species. Some of this information may be gained by examining stomach contents of harbor porpoises caught in Mid-Atlantic fisheries. Thus, the workshop recommended that more stomachs be collected and analyzed. Another approach discussed was to estimate how long a harbor porpoise can go without food before its condition declines. This could determine how close the link between distribution of harbor porpoises and their prey has to be. The group recommended that estimates of biomass over the study area would be a better unit of measure of fish abundance, and that commercial catch data might supplement the trawl survey data to provide a more complete description of the distribution of prey species.
- Examine potential competitors, for example, dogfish.
- Use sighting rates of both numbers of harbor porpoises and numbers of groups in future GAM correlation analyses.
- Stratify prey length curves by season caught, age and sex of harbor porpoises that ate the prey to examine if prey selection exists.
- Investigate characteristics of harbor porpoise's non-summer habitat. First,

though, it is necessary to determine where animals are during non-summer months. It was recommended that large-scale aerial surveys not be conducted during winter months because of low sighting rates from airplanes and the potential that non-summer harbor porpoise densities are too low to be detected by airplanes. Instead, narrow the areas to be surveyed by equipping animals in the Bay of Fundy during the fall with tags; thus, tracking animals into their wintering grounds. In addition, to speculate on locations of potential wintering grounds, it was recommended to use existing data in two ways. One, plot all track lines that were surveyed during past winters in good conditions (Beaufort sea states 0-2). This might indicate areas that have not been surveyed. Two, use existing non-summer aerial sighting rates (corrected for by g(0)) as a predicted harbor porpoise density during non-summer months. Then, assuming this predicted density is uniformly distributed over the oceans, determine the area necessary to house all the animals estimated in the Gulf of Maine/Bay of Fundy region.

BIOLOGICAL SIGNIFICANCE OF BYCATCH

During the 1992 workshop, biological significance of harbor porpoise bycatch was evaluated by comparing the estimated potential population growth rate (λ) with the ratio of annual total bycaught animals to total population abundance (mortality rate). Because it was assumed Gulf of Maine/Bay of Fundy harbor porpoises were isolated from other putative subpopulations, the mortality rate was computed using the estimated annual number of bycaught harbor porpoises in the Gulf of Maine sink gillnet fishery and the population abundance was estimated using data from the August 1991 sighting survey. The limitations of this procedure are discussed in NEFSC (1992).

EFFECTS OF AGE AND SEX STRUCTURE

One of the limitations of the comparison just discussed is that it does not account for possible nonrandomness in the age and sex composition of the bycatch. Age and sex compositions of the western North Atlantic harbor porpoises are available from bycatch data from the mid-1980s, and from some strandings data from the early 1980s. These data indicate that males and females occur about equally often in the bycatch and strandings, and a wide age range is found in the samples. Although there may be some selectivity by the bycatch gear, there was no indication that bycatch was taken principally from any particular age range. However, the maximum age recorded for a western North Atlantic harbor porpoise in strandings or bycatch was 17, compared to 24 from California and the United Kingdom. This difference may be an artifact of sampling or an indication that mortality rates in western North Atlantic harbor porpoises are higher than those for harbor porpoises found in other regions. The workshop suggested that this possibly higher mortality rate could be due to bycatch or to some natural process. The relevant data to evaluate these alternatives were not available. However, it was noted that rates of pregnancy and lactation are higher in the western North Atlantic than in California.

In conclusion, given that gillnets in the Gulf of Maine do not appear to be selective for a particular age or sex group, the workshop concluded that there was no need to use age- or sex-specific models to evaluate the biological significance of bycatch, and that it was appropriate to summarize the impact of bycatch on any single population through annual bycatch mortality rates.

RECOMMENDATIONS:

- Investigate reasons for the difference in mortality rates by comparing age composition and fecundity data from California, western North Atlantic and United Kingdom harbor porpoises.

POPULATION STRUCTURE AND ITS IMPLICATIONS FOR ASSESSMENT

When evaluating the mortality rate, a key issue is the extent and timing of mixing among harbor porpoises in the western North Atlantic. A summary of our present knowledge about mixing is as follows. Harbor porpoises in the western North Atlantic give birth in May and conception occurs from late June to early July. The distribution of harbor porpoises during these periods are poorly understood. From July to September, three geographically separate summer post-breeding groups are known: northern Gulf of Maine and lower Bay of Fundy region (GOM/BOF), Gulf of St. Lawrence, and along Newfoundland. Bycatch in sink gillnets are known to occur in all three summering areas. Outside the summer period, our knowledge of harbor porpoise movements is extremely limited. It is known that gillnets in the southern Gulf of Maine take harbor porpoises during the spring and fall. In addition, during winter, some harbor porpoises strand along the mid-Atlantic coast of the United States from Cape Hatteras to the southern Gulf of Maine. Some of these stranded animals bear evidence of recent entanglement in fishing gear (Haley and Read 1993). Thus, it is not known if Gaskin's hypothesized subpopulations are discrete or mix during some times of the year, and which of these subpopulations are taken in gillnets during the different times of the year.

Because of this limited knowledge of seasonal movements and discreteness, the workshop hypothesized several possible population structures, and, for each hypothesis, determined how the biological significance could be evaluated. Suppose, for example, that summer groups are "traditional"; that is, a great majority of harbor porpoises show strong behavioral affinities to a particular summering area, returning to the same area year after year and staying there all summer. If this reflects the true population structure, bycatch from the GOM/BOF traditional group would not affect abundance in Gulf of St. Lawrence's or Newfoundland's tradition groups. In this case, biological significance of bycatch would be best assessed separately for each traditional group. However, suppose instead that there is considerable inter-change between the summer groups, either within a year or from year to year. In this case, bycatch from any one summer group could affect the abundance of <u>all</u> summer groups after at most one year. The most appropriate assessment would then be to compare total annual bycatch from all regions with total abundance from all summer groups. The issue may actually be more complex than these examples suggest, however, because the degree of mixing may differ between summer and the rest of the year. More detailed hypotheses are discussed next.

It is important to note that the utility of the mortality rate depends on whether summer (post-breeding) groups are traditional, rather than on the degree of interbreeding between different parts of the western North Atlantic. To illustrate this, consider what would happen in the GOM/BOF following the complete elimination of its summer group. If the summer groups are traditional, then the GOM/BOF would not be quickly repopulated regardless of any possible interbreeding between animals from the GOM/BOF and other summer groups, because, under this assumption, calves follow their mothers and there would be no mothers going to GOM/BOF. On the other hand, if there is extensive mixing between summer groups, repopulation could be fairly swift; this would apply whether or not there are genetically separate groups. If mixing is extensive but there are three genetically separate groups, then the effect of bycatch on any one such group would be similar to that on all of the animals in the western North Atlantic as a whole. Without better information on (1) breeding locations, (2) the relationship between individual animals' breeding grounds and summer residences, and (3) genetic structure, it was impossible to consider the biological significance of bycatch at the level of genetically separate groups.

Neither available genetic data nor abundance survey results were sufficient to determine whether the summer groups are traditional. If the difference between the 1991 and 1992 estimates is due to an influx of animals, then the traditional group hypothesis is untenable. However, if the difference simply reflects sampling error (which is possible given the estimated variability), then the traditional group hypothesis is neither strengthened nor refuted.

Until there is better information on genetic structure and movement, no one approach is clearly best for assessing the biological significance of by-catch. However, by considering several scenarios corresponding to different genetic structures, a range of possible bycatch impacts can be determined, provided appropriate data are available. The workshop considered a number of such scenarios covering different patterns of summer and rest-of-year mixing, described below. While there are other possible scenarios (partial mixing, for example, or two rather than three discrete traditional groups), the workshop considered that, although some of the scenarios are unlikely to correspond to reality, assessments of bycatch based on this range could span the likely range of impact.

A: Three traditional groups, separate throughout the year. Non-summer bycatch in GOM/BOF and Mid-Atlantic is assumed to be taken from GOM/BOF group only. The non-summer locations of Gulf of St. Lawrence and Newfoundland groups are unknown.

B: Three traditional groups, separate in summer but mixed during the rest of year. Summer bycatch in GOM/BOF is taken from GOM/BOF group only; rest-of-year by-catches from the Gulf of Maine and Mid-Atlantic are taken from more than one summer traditional group.

C: No separate traditional groups; almost all western North Atlantic harbor porpoises concentrate in GOM/BOF during summer.

D: No separate traditional groups; many animals outside GOM/BOF during summer.

These scenarios are not equally likely. In particular, B was thought more plausible than A. Also, it was noted that estimated bycatch in Gulf of St. Lawrence during summer is substantial, suggesting that summer abundance in Gulf of St. Lawrence is unlikely to be negligible compared to summer abundance in GOM/BOF. For this reason, C was thought much less likely than the other scenarios but, it still warranted consideration as a bound on the possible impacts.

The workshop recommended that schemes for estimating mortality rates be specified for the different scenarios. These specifications assume that abundance is estimated during summer and separately for each summer group. If other estimates of abundance became available (for the whole western North Atlantic during the breeding season, for example), then the specifications would require adjustments. For each population structure scenario, the mortality rate would be estimated as follows:

A: Divide annual bycatch by abundance, separately for each summer group.

B: This mortality rate has a summer and non-summer component. To derive the summer component for each summer group, divide summer bycatch by the respective summer abundance. To derive the non-summer component, divide total non-summer by-catch by total abundance for all summer groups.

C: Divide total annual bycatch from all areas by GOM/BOF summer abundance plus (as a minimum) summer bycatch from Gulf of St. Lawrence and Newfoundland. Note that this assumes 100% mortality on animals in Gulf of St. Lawrence and Newfoundland during the summer.

D: Divide total annual bycatch by total abundance, for all areas together.

These specifications do not indicate exactly what estimate of abundance to use. For GOM/BOF (the only group for which estimates of abundance are currently available), scenarios A, B, and C all implicitly assume that the discrepancy between the 1991 and 1992 estimates is a result of sampling variability. On that basis, an appropriate overall estimate of abundance would be a weighted mean of the two estimates, weighted by the inverse of their respective variance estimates, 47,200. Under scenario D, however, it is possible that the discrepancy reflects an influx of animals in 1992, and an unweighted mean might, therefore, be a more appropriate estimate of abundance, 52,500.

DATA AVAILABILITY

To assess the biological significance of bycatch under scenarios A-D, estimates of abundance and bycatch stratified by season and area are required. Only four estimates are available or expected to be so in the near future: summer abundance in GOM/BOF, summer bycatch from northern United States Gulf of Maine, non-summer bycatch from southern United States Gulf of Maine, and summer bycatch from Gulf of St. Lawrence. The missing estimates are: summer abundance in Gulf of St. Lawrence and Newfoundland, summer bycatch in the Bay of Fundy and Newfoundland, and non-summer bycatch in the Mid-Atlantic, Gulf of St. Lawrence and Newfoundland. The workshop discussed ways to make rough estimates of these but felt unable to produce numbers reliable enough to be useful given the data available.

However, it is still possible with existing data to make some estimates of mortality rates under some of the scenarios: namely, for GOM/BOF group under A, GOM/BOF group in summer only under B (which would be negatively biased if treated as a mortality rate estimate for the whole year), and whole western North Atlantic under C (which would be negatively biased due to no bycatch estimates from Newfoundland). The absence of any bycatch estimate for Mid-Atlantic is a source of negative bias for all of these. If the Bay of Fundy summer bycatch is ignored, then all the resulting mortality rates will be negatively biased. If the procedure to produce rough bycatch estimates (see the bycatch section of this paper) is used to estimate summer bycatch in the Bay of Fundy, then the bias of the resulting mortality rate is unknown because the direction of bias of the rough Bay of Fundy bycatch estimate is unknown.

Because these calculations cannot be done for all scenarios, the actual mortality rate for the whole population or for any traditional group, if it exists, may lie outside the range that can be calculated now or soon. In particular, confidence intervals for any given scenario cannot be interpreted as representing likely upper and lower bounds of the mortality rate, for two reasons: (1) the scenario may not be a good approximation of reality, and (2) the likely degree of error in extrapolating Bay of Fundy rough bycatch estimates cannot be determined using the methodology proposed. The confidence intervals do, however, provide an estimate of how precisely the mortality rate could be estimated if: (1) population structure and movement patterns were known, and (2) estimates of bycatch and abundance of comparable precision to those now available for Gulf of Maine were available for all relevant areas.

In conclusion, the workshop was unable to assess the biological significance of bycatch of harbor porpoises because of lack of information on genetic population structure, seasonal migration patterns, and estimates of bycatch and abundance for most areas in the western North Atlantic.

RECOMMENDATIONS:

- After recalculating the Gulf of Maine annual bycatch and producing a rough estimate of summer bycatch in the Bay of Fundy, under scenario A estimate the mortality rate for the GOM/BOF summer group. It was recognized that this mortality rate value will be negatively biased because bycatch from the Mid-Atlantic is not included. However, because of the uncertainty of the magnitude of Bay of Fundy and Mid-Atlantic bycatch, the amount of negative bias is unknown.
- Because scenario B was thought to be the more likely population structure, it was desired to estimate the mortality rate under this scenario. Due to lack of data, the annual mortality rate estimate, under scenario B, will have to wait until more data are available. However, the summer component of this mortality rate can be calculated after the Gulf of Maine summer bycatch estimate is recalculated and the Bay of Fundy summer bycatch estimate is extrapolated.

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APPENDIX 1
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APPENDIX 2

AGENDA OF WORKSHOP HELD FEBRUARY 23-25, 1994

Wednesday

9:00-9:45 Introduction
- Welcoming by Allen Peterson
- Goals of meeting
  - Organization/agenda of meeting

9:45-11:00 Population estimates
- Gulf of Maine/Bay of Fundy (Palka)
- Gulf of St. Lawrence
- Newfoundland
- Greenland

11:00-12:00 Units of bycatch and gear characteristics of the bycatch
- (Northridge, Larrivée, Bisack)

12:00-1:00 Lunch

1:00-5:00 Kill estimates or bycatch rates
- Bay of Fundy (Trippel)
- Gulf of St. Lawrence
- Newfoundland
- Greenland
- Mid-Atlantic
- Gulf of Maine
  - Estimates (Bisack)
  - Sources of biases (Bisack, Walden, Fiorelli)

Thursday

9:00-10:00 Growth rate estimate
- Method (Brault, Caswell)
- Results
- Comparisons between this estimate and others

10:00-11:00 Population structure
- Review of previous studies
  - (Smith, Lockyer, Hohn, Read)
- Discuss pros and cons of methods
- Propose future work

11:00-12:00 Define concept of habitat requirements

12:00-1:00 Lunch

1:00-5:00 Habitat requirements
- Present new information
  - Food habits (Read)
  - Spatial correlations (Northridge, Palka)
  - Energetics (Brodie)
- Revise list
- Proposed research needs

Friday

9:00-10:00	Methods to reduce bycatch
	Closure areas (Fiorelli)
	Gear modifications (Northridge)
	Propose other methods
10:00-11:30	Biological significance of bycatch/status of population
	Definition of (Smith)
	Compute results
	Biases and uncertainties
	Future research needs
11:30-12:00	Compile research needs
12:00-1:00	Lunch
	Finish discussions

APPENDIX 3
LIST OF WORKING PAPERS

WP1. Smith, T., Palka, D. and Bisack, K. Biological significance of bycatch of harbor porpoise in the Gulf of Maine demersal gillnet fishery. Northeast Fisheries Science Center Reference Document 93-23. NMFS/NEFSC Woods Hole, MA.

WP2. Bisack, K. Estimates of total bycatch in the Gulf of Maine sink gillnet fishery. Northeast Fisheries Science Center Reference Document 93-11. NMFS/NEFSC Woods Hole, MA.

WP3. Bisack, K. Recommendations for estimating bycatch. Manuscript.

WP4. Northridge, S. and Bisack, K. Appropriate measures of CPUE in the Gulf of Maine sink gillnet fishery. Manuscript.

WP5. Larrivée, M.-L., Kingsley, M.C.S. and Barrette, C. Effect of fishery characteristics on bycatch of harbour porpoise in the Gulf of St. Lawrence (Canada). Manuscript.

WP6. Trippel, E. Preliminary results of spatial patterns of harbor porpoise bycatch in the Bay of Fundy area. Canadian Fisheries and Oceans, New Brunswick, Canada. Oral Presentation.

WP7. Smith, T. Draft of Population structure of puffin' pigs, *Phocoena phocoena*: Preliminary proposal for an international research project. Manuscript.

WP8. Rosel, P.E., Haygood, M.G. and Dizon, A.E. What genetic information can tell us about harbor porpoise population structure. Manuscript.

WP9. Hohn, A., Lockyer, C. and Read, A.J. Summary report: Discriminating stocks of small cetaceans from tooth characteristics. Manuscript.

WP10A. Caswell, H. Uncertainty analysis of Population growth rate. Manuscript.

WP10B. Caswell, H., Brault, S., Read, A., Smith, T. and Barlow, J. Rate of increase of harbor porpoise populations: Estimation and uncertainty. Manuscript.

WP11. Berggren, P., Read, A.J., Gaskin, D.E. and Kraus, S.D. Trends in harbour porpoise (*Phocoena phocoena*) relative abundance in the Bay of Fundy, New Brunswick, Canada. (Submitted to Can. J. Fish. Aquat. Sci.).

WP12. Read, A.J., Craddock, J. and Neimanis, A. Seasonal variation in diets of harbour porpoises from the Gulf of Maine. Final contract report to NMFS/Northeast Fisheries Science Center. NMFS, 166 Water St., Woods Hole, MA 02543.

WP13. Brodie, P. Gulf of Maine/Bay of Fundy harbour porpoise: Some considerations regarding density dependence, energetics, and species interactions. Manuscript to be submitted to IWC special issue.

WP14. Northridge, S. Preliminary results of a G.I.S.-aided mapping study of harbor porpoise and fish distributions in the Gulf of Maine. Manuscript.

WP15. Westgate, A.J., Read, A.J., Berggren, P., Koopman, H. and Gaskin, D.E. Diving behaviors of harbor porpoises in the Bay of Fundy. Manuscript.

WP16. Potter, D., Palka, D., Read, A. and Nicolas, J. A field study of the spring migration and habitat partitioning of harbor porpoise in the Penobscot Bay area of central Maine. Manuscript.

WP17. Palka. D. Correlations between sighting rates of harbor porpoises and environmental factors using sighting survey data collected in 1992 and 1993. Manuscript.

WP18. Bjørge, A., Øien, N., and Aarefjord, H. Preliminary studies of diet composition and habitat preferences of harbour porpoise in Northeast Atlantic. Manuscript.

WP19. Walden, J. Determining gillnet fleet size in New England: A report on the special gillnet effort study. Manuscript.

WP20. Lien, J. Bycatch of marine mammals in fisheries around Newfoundland (section of paper). Manuscript.

WP21. Palka, D. and Read, A. Description of the habitat of Northwest Atlantic harbor porpoise. Manuscript.

WP22. Rosel, P. and Smith, T. Report from the Special Session on Population structure of harbor porpoise 22 Feb 94. Manuscript.

WP23. Payne, M. Harbor porpoise/gillnet interactions in the Mid-Atlantic region (New Jersey south through Virginia). Manuscript.

APPENDIX 4
DRAFT DESCRIPTION OF RESEARCH PROPOSAL TO BE DEVELOPED

Collaboration on Atlantic Porpoise Population Structure (CAPPS)

INTRODUCTION

The bycatch of harbor porpoise, *Phocoena phocoena*, in the North Atlantic has increasingly been recognized as a major environmental problem in the waters of several nations. Where both the level of bycatch and abundance have been estimated, the levels have exceeded likely sustainable levels (NEFSC 1992, IWC 1992), although the information needed for a complete assessment of the status of the populations involved has been lacking.

These concerns are reflected in a resolution of the International Whaling Commission (IWC) during its 1993 meeting in Kyoto, Japan (Annex A). The resolution calls for the assembly and reporting of information on the status of harbor porpoise in the North Atlantic to the Commission during its 1994 meeting. Similarly, the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) comes into force in the eastern side of the North Atlantic at the end of March 1994. This agreement includes as one emphasis the issues of the bycatch of small cetaceans. To promote resolution of this problem, ASCOBANS has agreed to support actions and direction of the IWC on problems related to small cetaceans (Report of the Preliminary Meeting of ASCOBANS Range States, October 1993, Cambridge).

Levels of bycatch and of abundance have been estimated in some areas, and plans are being implemented to develop additional estimates in other areas (Small Cetacean Abundance in the North Sea). However, a major uncertainty in planning these research activities continues to be the population structure of the affected animals. Thus, the appropriate size and location of the areas to be surveyed to allow the accurate determination of the biological significance of the bycatch is not known.

The existence of 14 separate populations has been hypothesized in the North Atlantic (Gaskin 1993), although more recent work has raised uncertainties about the degree of interchange among animals in some of these areas (Wang 1993; Rosel 1992; Andersen 1993). Improving our understanding of the population structure of this species is essential in order to interpret bycatch and abundance estimates in the future. If biologically separate populations are not recognized, there is a danger of underestimating the biological significance of the bycatch from one of the populations. If, on the other hand, the assumed separations are not real, there is a danger of overestimating the actual significance, which might result in unnecessary restrictions on fishing activities. However, it is likely that harbor porpoise occupying some of the adjacent areas may not be genetically distinct, but nonetheless have ecologically significant levels of interchange only rarely. To be sure that management actions in response to bycatch levels are well designed, it is important to understand the nature of the population structure of harbor porpoise, be it discrete populations with limited exchange or groups of animals with variable interchange rates.

The resolution of this uncertainty will require the collection, analysis, and integration of information from several types of harbor porpoise samples from throughout the North Atlantic. An international collaboration of scientists in this region is proposed. The collaboration is proposed to be coordinated through the Scientific Committee of the IWC, in collaboration with the International Council for the Exploration of the Seas (ICES) and ASCOBANS, and cooperating organizations. The project is planned to require two years, and to produce an integrated description of the population structure of this species in the North Atlantic.

HYPOTHESIS

Gaskin (1984) proposed fourteen subpopulations of harbor porpoise in the North Atlantic, based largely on distribution data (Table 4-1). These data were supplemented by major biogeographic boundaries that might serve as barriers to movements. As a starting point for an examination of population structure of this species in the North Atlantic, it seems reasonable to consider four alternative hypotheses:

- H_3: one panmictic population unit across the North Atlantic
- H_2: less than or equal to fourteen units with considerable exchange
- H_1: less than or equal to fourteen units with little exchange
- H_0: fourteen discrete population units

Here, "discrete" means that the amount of exchange between units is small enough that the units have been isolated from one another over recent geological time. H_1 suggests that the number of migrants per generation is very small, so that the units could be discriminated using standard genetic techniques. H_2 suggests that the units are ecologically distinct, but that sufficient exchange occurs among them that they can not be distinguished using genetic techniques or morphological measurements.

Information presented in WP-22 suggests that H_3 and H_0 have been invalidated by morphological and genetic evidence. This proposal, therefore, is for a set of studies using a range of complementary methods to determine both the number of population or subpopulation units, and the degree of exchange among them, and thereby to distinguish between H_1 and H_2.

Table 4-1. Fourteen subpopulations of harbor porpoise in the North Atlantic proposed by Gaskin (1984) based on distribution patterns

1. Newfoundland
2. West Greenland
3. Gulf of St. Lawrence
4. Gulf of Maine
5. Southeast Greenland
6. Iceland and Faroe Islands
7. Ireland and West U.K.
8. English Channel
9. North Sea
10. Baltic Sea
11. Norway
12. Barents-White Sea
13. Iberian Peninsula
14. West Africa

STUDY DESIGN

A range of scientific methods for determining population structure will be applied to existing and new biological samples from across the North Atlantic. Analysis of bycaught and stranded samples from each of the 14 hypothesized population areas will be attempted, with sample sizes to be determined separately for each of the methods being used.

Five methods or groups of methods will be emphasized: movements, biological processes, chemical indicators, morphology, and genetics. These tools each have different strengths depending on the actual population structure (Table 1 in main text). Analyses will be conducted by scientists at laboratories in several countries bordering the North Atlantic and the North and Baltic Seas. Workers applying methods in each of these four groups will collaborate to ensure adequate sample sizes and consistent application of the methods. Results from individual laboratories will be published as appropriate, with full participation and recognition of the contributions of individuals collecting samples and conducting analyses. The collaborating groups will assemble the data from the individual laboratories into common databases, and those databases will be jointly analyzed by representatives from the individual collaborations.

Overall coordination of the study will be by representatives of the collaborating methodological groups and others. Specifics of the collaborating methods groups and of the overall coordination will be developed within the Small Cetacean Subcommittee of the International Whaling Commission. The matter of organization and management of the program is considered next.

ORGANIZATION AND SCHEDULE

The research program will involve scientists working in research institutions in many countries around the North Atlantic. The program will be organized through a coordinating committee that will ultimately hold responsibility for achieving goals and schedules defined in the proposal. The program comprises several research studies that will be effected by key laboratories and persons overseeing individual studies according to their specialty and onsite facilities for undertaking the work. These persons will liaise regularly with the coordinating committee on progress.

The proposal will identify those scientists actively participating in the project, and will compile potential sources of specimens for sampling, specify protocols and laboratory methodologies to be used for consistency among researchers, and the specific data elements to be collected for each specialty study. Compilation of existing data will be completed as a basis for determining minimum and target sample sizes. A list of potential participants is being developed.

Whilst the program is proposed as an integration of international research effort, individual collaborators will be required to seek and establish their own funding from international and/or local national sources. It is intended that the outlined program will be presented in the form of a research proposal (to be developed at the NEFSC, Woods Hole) to the following inter-governmental organizations known to be actively concerned with small cetaceans: IWC, ICES, and ASCOBANS, for comment and endorsement, and also potential funding or in-kind support. The proposal will be presented to the three organizations as follows: May 1994 for IWC; September 1994 for ICES; September 1994 for ASCOBANS. It is hoped that the IWC Scientific Committee may initially advise on the selection of the key persons and laboratories to be involved both on the coordinating committee and in the research studies.

Identification and initial analyses of samples will not commence until the later half of 1994, but are expected to be completed within 12 months. Specialty-specific databases will begin to be created by mid-1995, with feedback for obtaining further samples to fill gaps as they emerge. Individual specialty study groups should meet before the end of 1995, and results of those meetings will be analyzed at a workshop in 1996, and compiled into a report.

APPLICATION OF RESULTS

The results of the study will be of primary importance in determining the correctness of the hypothesized population structure for North Atlantic harbor porpoise (Gaskin 1984). The conclusions will provide the necessary information for interpreting information on bycatch and abundance levels in terms of the biological significance of the bycatch. These results will be especially important in areas where harbor porpoise are subject to bycatch mortality by fishermen from more than one country, and will provide a sound basis for management generally.

The comparison of the results obtained from the simultaneous application of several methods that have been used in studies of the population structure of cetaceans, will improve our understanding of the applicability and statistical power of the several methods in different situations. For example, the relative power of the two principal genetic methods to be used to detect the degree of population discreetness will be illustrated, allowing selection of the more effective and cost efficient method in future studies of cetaceans. Similarly, results from methods that emphasize interchange of animals on ecologically relevant time scales will be compared with those emphasizing interchange on evolutionary time scales. This comparison will improve our understanding of the appropriateness of these two types of approaches in determining population structure. More generally, the results will help us to understand the degree to which different methods are complementary.

Finally, the extensive collaboration among scientists using the same research methodology will result in improvements in the consistency of application of the methods. This will allow improved technical capabilities among scientists throughout the North Atlantic countries.

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Annex A: Resolution on North Atlantic Harbor Porpoise by the International Whaling Commission, May 1993

RESOLUTION ON HARBOUR PORPOISE IN THE NORTH ATLANTIC AND THE BALTIC SEA

RECALLING that at the Commission's 42nd, 43rd and 44th Annual Meetings, the Scientific Committee recommended as high priority that in the North Atlantic, bycatch mortality of harbour porpoise should be reduced, and further recommended that research be conducted to determine abundance, stock identity, bycatch levels, and pollutant levels;

RECOGNISING that considerable research has been initiated by member and non-member countries to address some of these needs, including in different regions, abundance, distribution, ecological requirements, vital rates, movements, stock identity, and bycatch mortality levels;

RECOGNISING that these studies need to be continued and additional research undertaken to provide a sound basis for understanding the status of the stocks of harbour porpoise throughout the North Atlantic and Baltic Sea in the face on continuing bycatch and other threats;

RECOGNISING the relevance of the Agreement of the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) for the protection of harbour porpoises;

The Commission RECOMMENDS:

(1) That Range States take action to meet the Scientific Committee's request for the collection and analysis of additional data on population distribution and abundance, stock identifies, pollutant levels, and bycatch mortality level;

(2) That Range States give high priority to reducing bycatches of harbour porpoise;

(3) That Range States report to the 46th Annual Meeting of the Commission on their progress in implementing the above recommendations.

(4) That information about the harbour porpoise be exchanged with the Interim Secretariat of the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas.